BLOCK-CAVING METHODS AT THE SUNRISE MINE PLATTE COUNTY, WYO.

BY F. L. WIDEMAN

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INTRODUCTION

This paper is one of a series on mining methods being published by the Bureau of Mines. It describes briefly mining practices at the Sunrise iron mine of the Colorado Fuel & Iron Corp., Platte County, Wyo.

The Sunrise mine is in the Hartville iron district in east-central Wyoming (fig. 1). The district covers part of the Hartville Mountains, a region of moderate relief in which erosional features have been formed by the dissection of a low plateau. Altitudes vary from 4,300 feet along the North Platte River to 6,000 feet in the uplift. The climate is semiarid, with hot summers and winter temperatures below zero for short periods. Grasses, cacti, yucca, and low desert shrubs grow at lower elevations. Cottonwood and boxelder trees and willows grow along permanent streams; juniper and coniferous trees are confined to the higher elevations.

Many of the employees at the mine live in the town of Sunrise and the nearby towns of Hartville and Guernsey. Some employees commute from towns as much as 30 miles away.

The iron ore is hauled 7 miles by the Colorado & Wyoming Railway to Guernsey and thence by Chicago, Burlington & Quincy Railroad or the Colorado & Southern Railroad to steel mills at Pueblo, Colo.

Most of the timber used at the mine is from Oregon, but some timber is obtained from the Laramie Mountains west of the district.

ACKNOWLEDGMENTS

Acknowledgment is made to members of the staff of the Colorado Fuel & Iron Corp. for their cooperation and courtesies. R. R. Williams, manager of mines, made helpful suggestions concerning the report. M. L. Sisson, superintendent, and H. B. Lynch, chief mine engineer, supplied much information about the mine. J. W. Johnston, mine engineer, conducted the author through the mine and assisted in preparing this report.

HISTORY

Indians roving through the Hartville area were the first to utilize the iron ores, using the soft red hematite for war paint. From 1880 to 1887 the deposits were explored for copper, and a smelter was built at Fairbanks, about 5 airline miles from Sunrise, to treat the copper ores. The significance of the iron-ore deposits was recognized during the copper-mining period, and there was considerable activity in locating mining claims after 1890. The colorado Fuel & Iron Co. (now a corporation) became interested in the district in 1898, and approximately 3 years later began mining iron ore by open-pit methods. After the ore body had been mined a few feet below the railroad-track level, two shafts were sunk, and mining continued to the third level by glory-hole methods. The block-caving system of mining

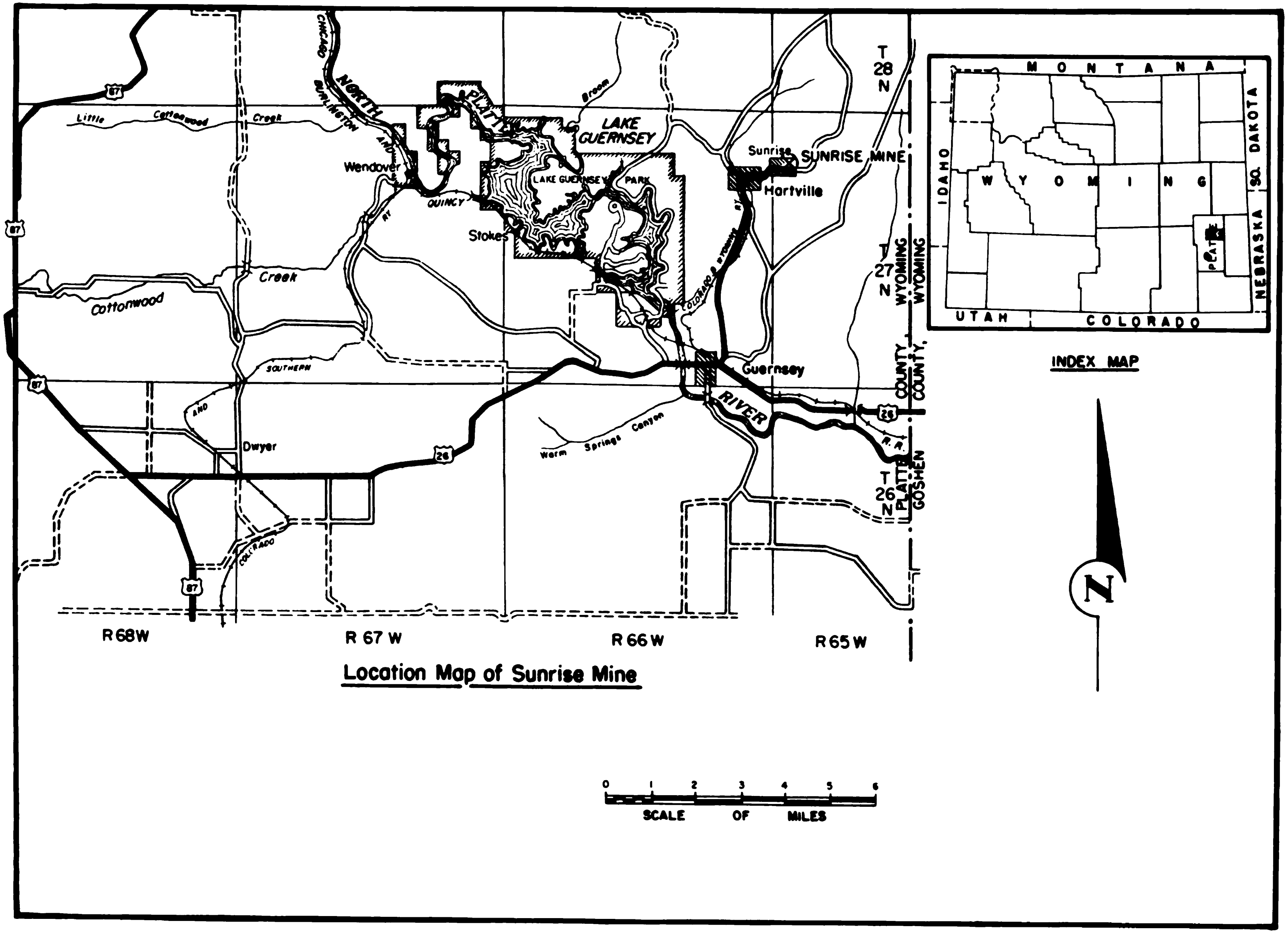

Figure 1. - Location map, Sunrise mine, Platte County, Wyo.

was introduced in 1929, but some ore was produced by glory-hole methods until 1941. Some sublevel caving was begun in 1941, and most of the ore produced by this method was mined from 1947 to 1953. Sublevel caving has been discontinued, and block caving is now used.

DESCRIPTION OF DEPOSITS

The iron ore bodies at the Sunrise mine occur as replacement deposits of hematite in steeply dipping, pre-Cambrian schists. The ore bodies are irregularly shaped lenses that are elongated in the direction of the strike of the bedding of the metamorphosed rocks. In horizontal plane the Sunrise ore body is roughly an S-shaped lens with dimensions of 1,600 by 600 feet and constricted to about 50 feet near the middle. The dip of the ore body varies from 45° to an overturned angle of 70°, but in general it is almost vertical. The Central ore body, which is more regular in shape but not as large, is approximately 6,000 feet northeast of the Sunrise ore body.

A series of flat-lying or gently dipping sediments (Carboniferous) was deposited unconformably on the pre-Cambrian complex. The capping over much of the Sunrise ore body consists of these flat-lying beds, which have a maximum thickness of about 300 feet in the vicinity of the mine.

The pre-Cambrian rocks have been folded into a complex synclinorium. Faults, particularly those that cut the beds at right angles, are common. The main iron-ore deposits are associated with brecciation that accompanied folding and faulting. The schists forming the walls of the ore body are weak and cave readily. The limestone and sandstone capping much of the ore body are strong and break into large blocks.

THE ORE

The ore is comprised principally of 2 varieties of hematite, 1 hard and gray and the other soft and brownish red, associated with minor quantities of siderite and limonite. The hard, gray portion of the ore contains cavities and fractures that facilitate fragmentation during caving. Mineralization grades from ore to barren rock, and limits of the stopes are governed by the iron content. Approximately 10 cubic feet of ore in place weighs 1 ton.

Gangue minerals are calcite, quartz, chalcedony, gypsum, barite, and pinite, a hydrous aluminum silicate. Bands of gangue and low-grade ore occur in the ore bodies. They add to the dilution of the ore and also hamper caving.

METHODS OF EXPLORATION

Core drilling, drifting, and raising are the methods of exploration used at the Sunrise mine. The position and the delineation of the ore bodies are determined by core drilling. Drifting and raising are continuations of development headings in fringes of the ore bodies, and it is difficult to differentiate between exploratory and development work in these areas.

Both surface and underground stations are used for core drilling. The practice is to drill from grid positions that can be occupied. Holes are fanned along grid lines from each position. The Central ore body was found by drilling from the surface. Information concerning extensions of known ore bodies is obtained principally by drilling from underground stations. The company prefers to drill holes of AX size in ore if possible and uses EX bits when it is not practical to continue with

AX drilling. Holes are usually started with NX bits and BX bits from the surface and underground, respectively. They are cased to prevent contamination of the samples. The maximum depth of the holes drilled from the surface is about 1,500 feet, and the maximum depth from underground stations is 800 feet. Holes from the surface are drilled by diesel- or gasoline-powered equipment; underground holes are drilled with air-driven machines. Holes from the surface and from some underground stations are drilled by drilling companies working under contract. Other holes from underground stations are drilled by company employees. Core recovery in ore varies considerably, depending upon the type of ore penetrated and on the quantities of gangue minerals present. Core and sludge samples are used to determine the grade of ore penetrated.

SAMPLING

Drifts and raises in ore are sampled at 10-foot intervals by cutting channels. The average grade of ore in an entire block is calculated from analyses of the channel samples and samples from diamond-drill holes. Composite samples are taken from three or four chutes when they are drawn. Chutes are sampled individually if the ore drawn is of marginal grade. Grab samples are taken from each railroad car while it is being loaded.

METHODS OF DEVELOPMENT

The Sunrise mine has been developed by three vertical shafts, one of which, Shaft No. 2, has been abandoned. Shafts Nos. 1 and 3 are in the metamorphic rocks some distance from the ore bodies (fig. 2). Shaft No. 1 is used to lower men and supplies to the fourth level. All ore is hoisted through shaft No. 3, which is also used to lower men and supplies to the third and fifth levels.

Drifts are driven from the shafts toward the known positions of the ore bodies in a manner to serve them most advantageously. The drifts are single track with a system of loops that make haulage virtually continuous in one direction (fig. 3).

Two plans are used in developing ore bodies (fig. 4):

1. Development for caving blocks with grizzly levels.

2. Development of caving blocks with slusher drifts.

Shafts

Shaft No. 1 was sunk at the time mining was changed from openpit to underground methods. It is a 3-compartment, concrete-lined shaft that measures 18 feet 4 inches by 6 feet inside the concrete. The shaft is used now as a service shaft for men and supplies for the fourth level, where a fringe of the Sunrise ore body is being mined. The shaft extends to the fifth level, but the part from the fourth to the fifth level has been converted into an ore pass.

Shaft No. 2 was sunk near the Sunrise ore body at the time the mine was worked by glory-hole methods. This shaft measures 9 by 12 feet outside of 10- by 12-inch timber. It has been abandoned because of its position near the ore body and also because it is too small and not suitably equipped for deep operations.

Shaft No. 3 or Wright shaft is the main working shaft at the mine (fig. 5). All ore is hoisted through this opening from the fifth level, and men and supplies for the third and fifth levels pass through the shaft.

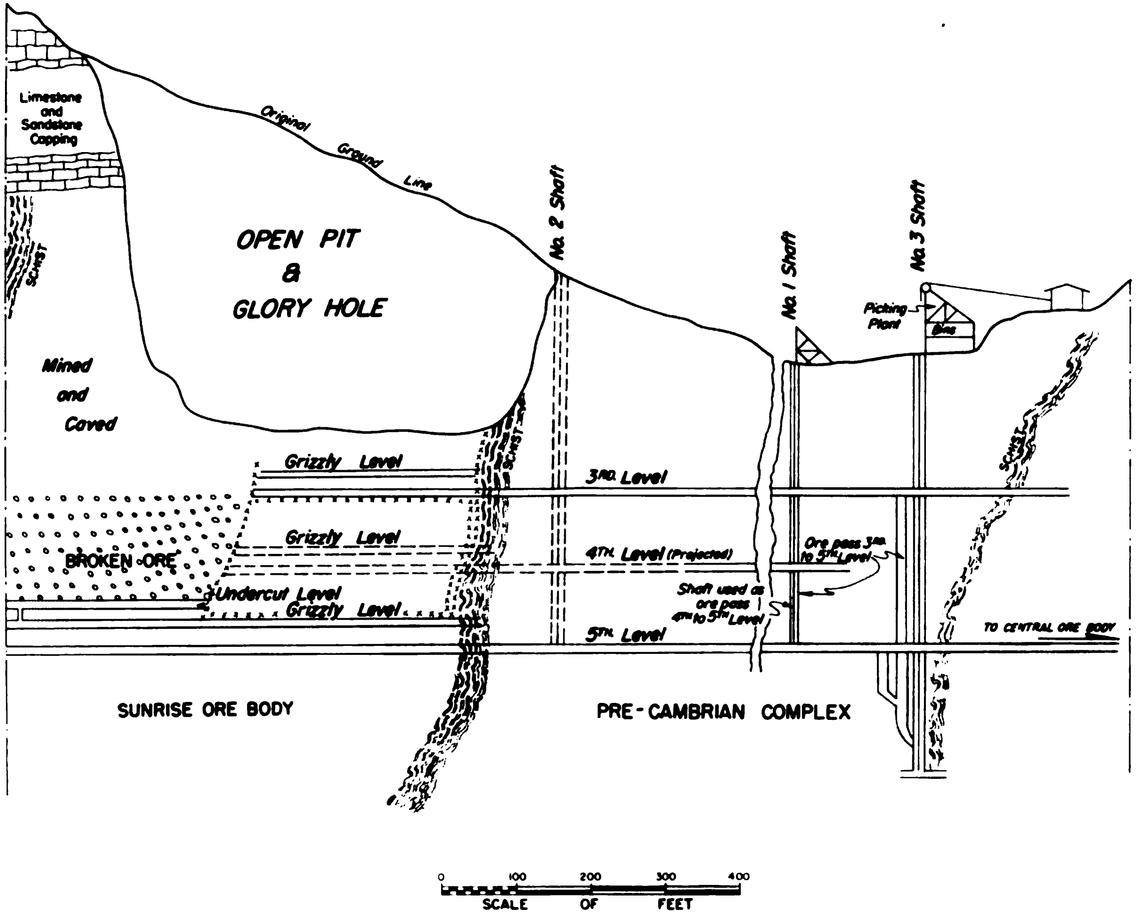

Figure 2. - Generalized section, Sunrise mine, Platte County, Wyo.

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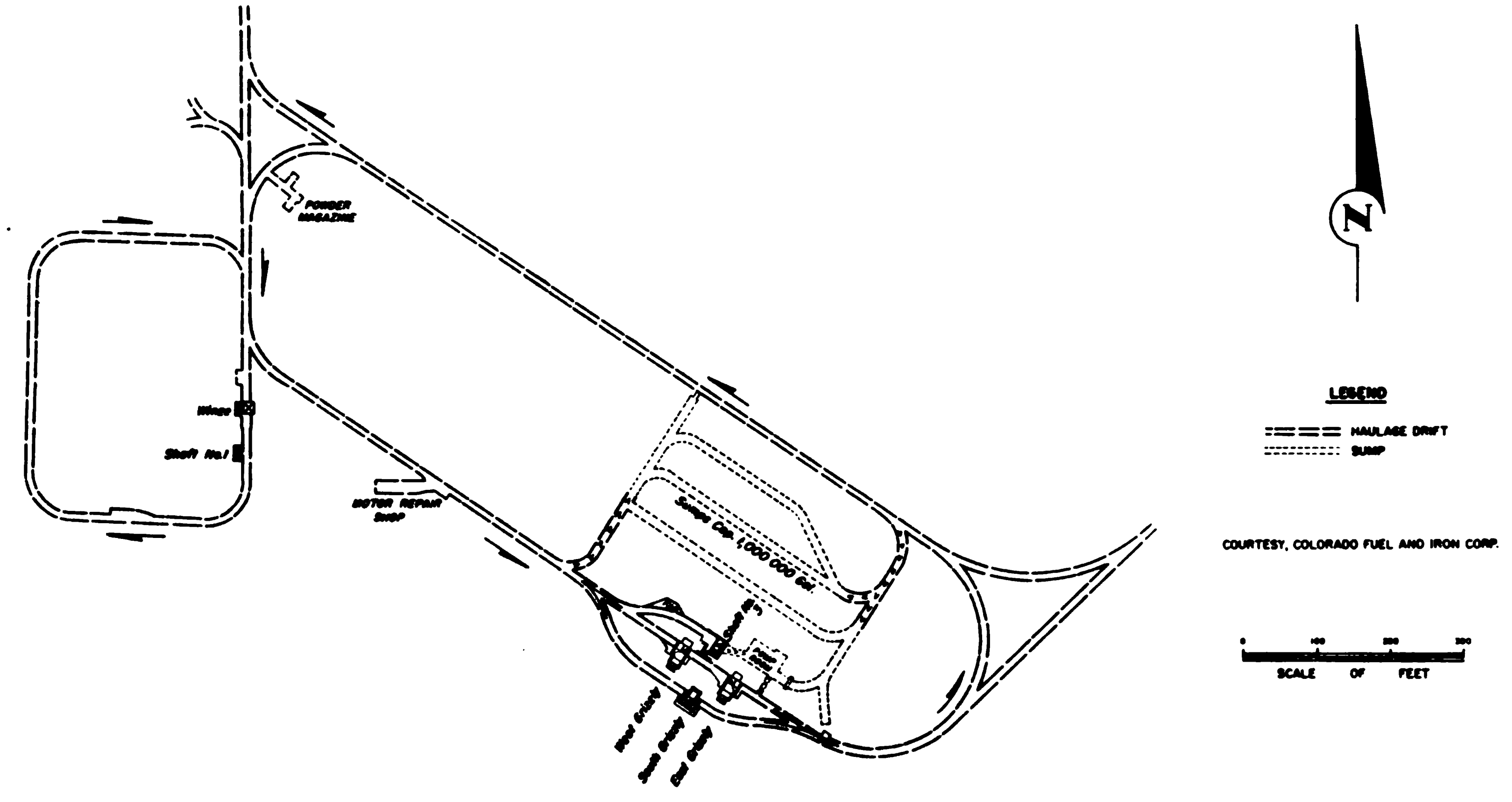
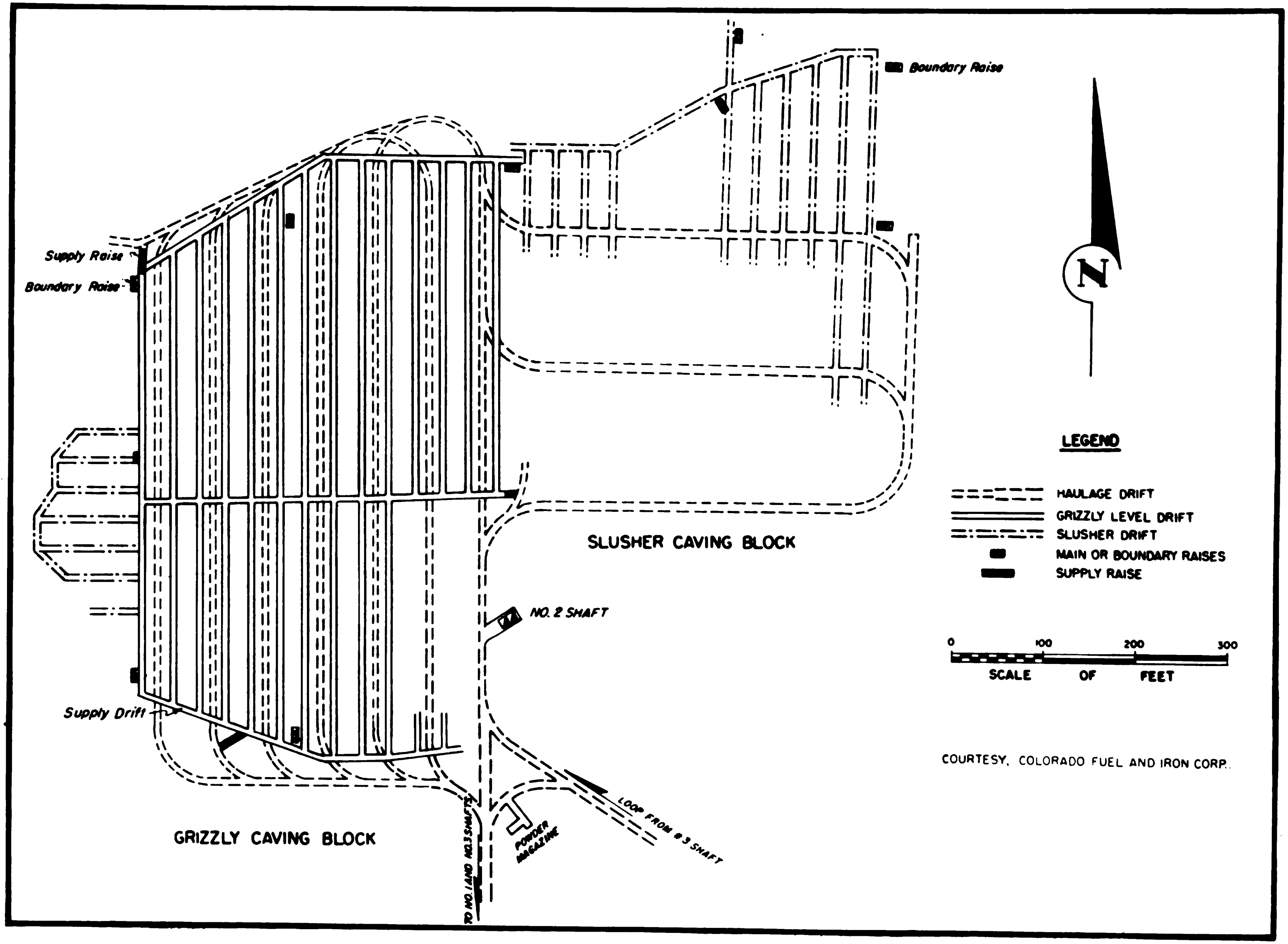


Figure 3. - Plan of typical haulage level, Sunrise mine, Platte County, Wyo.



COURTESY, COLORADO FUEL AND IRON CORP.

Figure 4. - Plan, development of Sunrise ore body, Sunrise mine, Platte County, Wyo.

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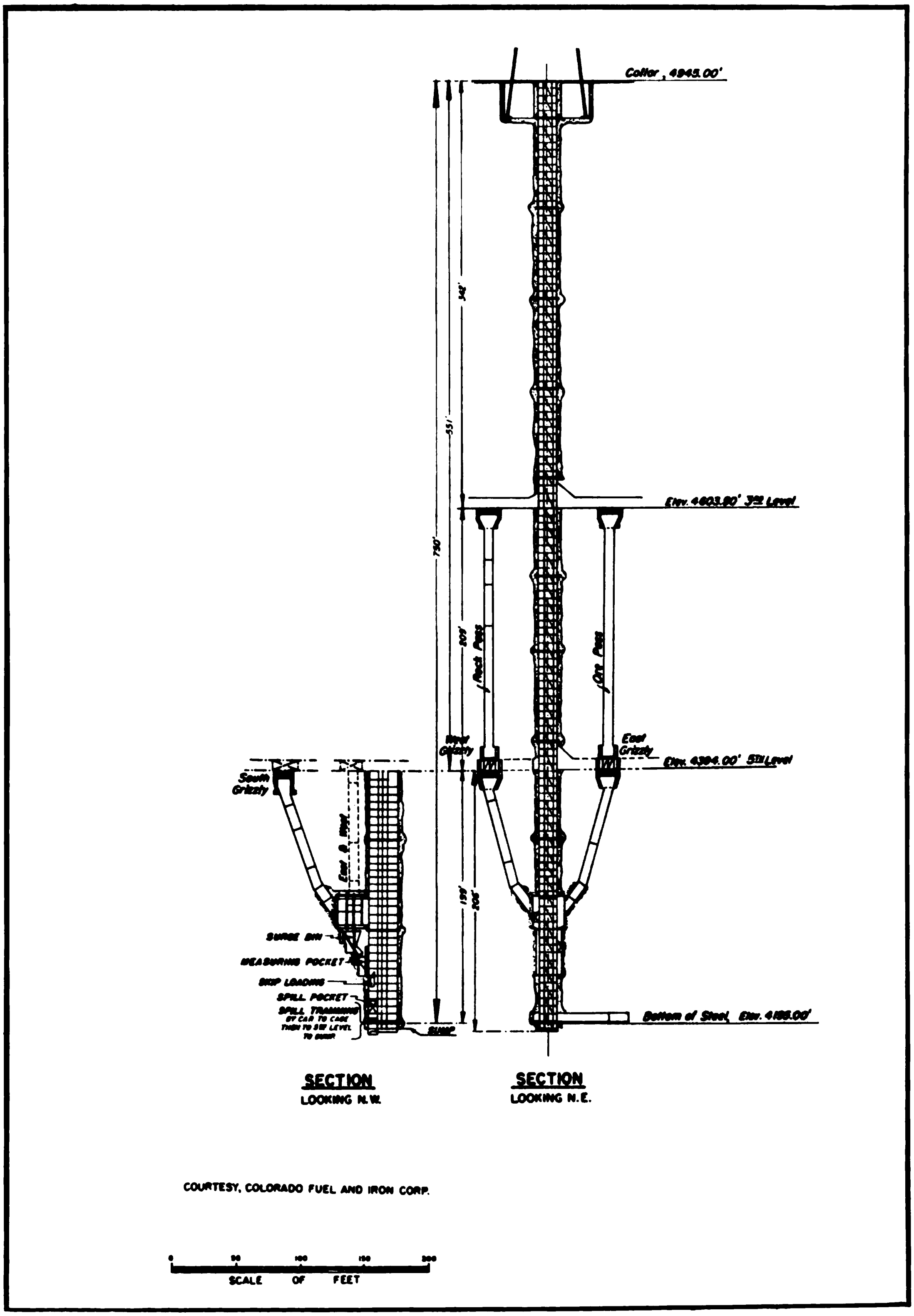

COURTESY, COLORADO FUEL AND IRON CORP.

Figure 5. - Section through No. 3 shaft, Sunrise mine, Platte County, Wyo.

The shaft has been described by M. L. Sisson[2] as follows:

> The new shaft is a six-compartment combination shaft measuring 14 feet by 22 feet 6 inches outside the steel sets. It has two compartments for skip hoisting of ore; one for cage hoisting of men and materials; one for the cage counter weight; one for air and water pipes and power cables; and one for a ladderway. The steel sets are of 25-pound 6-inch "H" section for wall plates, end plates and dividers with 4- by 4-inch angles for posts and vertical ties. The sets are placed on 6-foot centers. Bearing sets of 12- and 15-inch I-beams were installed every 72 feet. The shaft is concrete lined for the full depth of 750 feet. Wood guides, 6 by 8 inches, are used in the skip, cage, and counterweight compartments. Two main shaft stations are provided - one on the third level 350 feet below the surface, and one on the fifth level 550 feet below the surface. There is also a cage landing station at the bottom of the shaft, or the seventh lever...
>
> A single skip-loading point is provided; this is located 160 feet below the fifth level. The skip pockets are of concrete and steel construction and are served by three storage raises to the fifth level car-dumping points. Two transfer raises connect the raises on the fifth level with the third level. This permits the transfer of the third level production to the skip-loading point. This system of raises and pockets permits the storage of two grades of ore and of waste rock...
>
> The roller bearing head sheaves are 10 feet in diameter. The two upper sheaves, for the cage and counterweight, are 176 feet above the head frame foundation. The highest point of the head frame is 199 feet and the shaft collar is 26 feet above the top of the foundations...

Screen cloth, made of 5-gage wire and with 1-1/4-inch-mesh, separates the hoisting compartments from the manway compartment. The manway and cage compartments are separated by the same material.

> The skips dump into a steel hopper, in the top of the screening and picketing plant (fig. 6). In the bottom of the hopper is a 60-inch heavy-duty manganese steel pan feeder. This feeds the ore onto a 6-foot by 14-foot heavy-duty double deck vibrating screen which separates the ore into three sizes, -12" +5", -5" + 2", and -2". The two coarse sizes pass over two 48-inch picking tables, where any gangue is removed. A 100-ton bin, with independent railroad track and scale, is provided for each of the screened sizes. Provision is made for mixing any combination of sizes that may be desired for shipment. The screening and picking facilities can be bypassed and straight mine run can be loaded through one of the bins. Waste rock from the mine bypasses the screen and is carried by chutes to a 100-ton rock bin. From this bin the rock is trammed in a 50-ton side dump car by electric locomotive and wasted in the old open pit...
>
> The hoist house, a fireproof brick and steel structure, 190 feet long by 60 feet wide, houses the ore hoist, the man and material hoist, three compressors, two motor-generator sets, and accessory equipment.

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[2] Sisson, M. L., Raw Material Operations of Colorado Fuel and Iron: Skillings Mining Review, vol. 34, No. 12, July 7, 1945, pp. 1-2, 4.

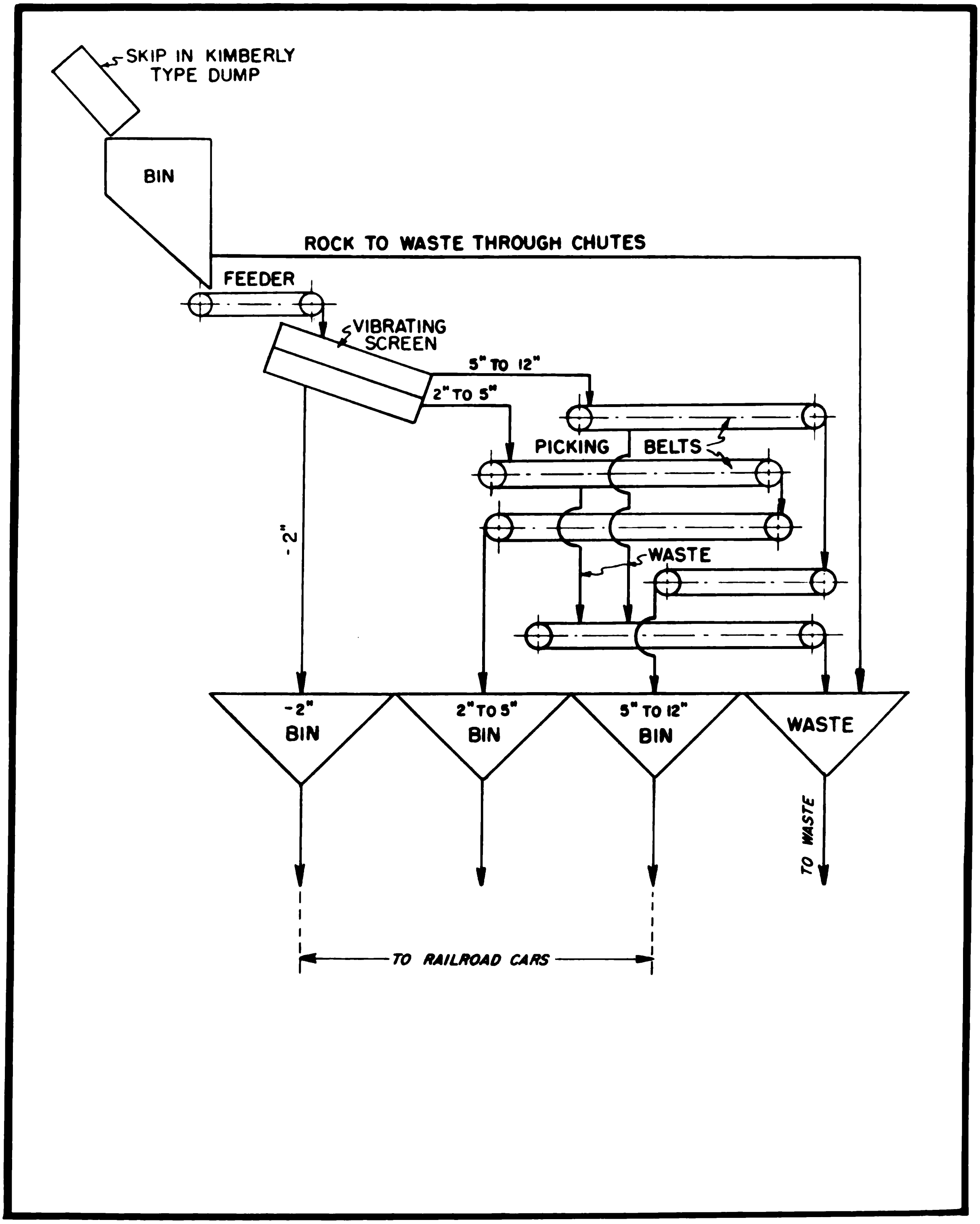

Figure 6. - Flow sheet, picking plant, Sunrise mine, Colorado Fuel and Iron Corp., Platte County, Wyo.

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The ore hoist is a double cylindrical drum, 10-foot diameter by 6-foot face, single gear reduction, driven by a 1,250 hp., d.c. motor, with a 1,000-k.w. Ward-Leonard type synchronous motor-generator set and amplidyne control. The man and material hoist is a double drum, 10-foot diameter by 6-foot face, single-gear reduction, powered by a 250-hp., 2,200-volt a.c. motor with magnetic control...

All hoisting cables are 1-5/8 inches in diameter. The ore skips, which operate in balance, have a capacity of 8 long tons each.

The man and materials cage is single deck, structural steel construction, 12 feet 6 inches long by 6 feet 10 inches wide; has a load capacity of 20,000 pounds. It is equipped with safety dogs, doors, and landing chairs. The cage operates in conjunction with a counterweight.

The whole plant is designed to handle 500 long tons per hour.

Drifts

Drifts are driven for three purposes: For haulage, for development of caving blocks, and for exploration. The drifts are driven 10 by 10 feet in the rough; and, where timbered, the bottom of the cap is 8 feet 2 inches above the rail.

Rock drills mounted on a jumbo and on airlegs are used to drill rounds in haulage drifts where they are driven in metamorphic rocks. The schist is more abrasive and more difficult to break than the ore.

The jumbo is a specially designed truck on which three drill jibs are mounted. It is equipped with a hydraulic roof jack that holds the unit by forcing the body of the truck down onto the flanges of the wheels, making it solid against forward or backward movement while drilling. The jibs are equipped with 4-inch rock drills, chain feeds, and 8-foot shells. Hydraulic pumps raise or lower and swing the jibs.

The airleg-mounted drills use 1-inch round steel and 1-3/8-inch and 1-5/8-inch tungsten carbide insert bits. A drill carriage is used in conjunction with the airleg-mounted drills (fig. 7). The carriage is 11 feet long with a folding deck approximately 33 inches above the track. The deck is made of 2-inch plank with steel cross cleats at 24-inch intervals. When the deck is unfolded, the carriage is about 8-1/2 feet wide. The drill carriage is equipped with air- and water-hose connections for three drills that are used simultaneously. Ladders 9 inches wide and made of 1-inch pipe are used in conjunction with the carriage. Cross bars are welded at 15-inch centers and sharpened prongs are welded on the ladders (fig. 7). The usual procedure in drilling a round is to spot the carriage about 15 feet from the face and lay the ladders on the bottom of the drift between the carriage and the face. The prongs are driven into the bottom of the drift. In drilling, the airleg stingers are advanced from one cross bar to the next one nearer the face whenever necessary. The rounds are started with the lifters. After the bottom part of the round is drilled, the carriage is pushed to the face. The locomotive or a few cars remain against the carriage to prevent its moving during drilling. The stingers of the airleg machines are advanced from cleat to cleat while the top part of the round is drilled from the deck of the carriage. Rock drills, hoses, and other drilling equipment are transported to and from the face on the carriage, which also serves as storage for the equipment. The carriage is used as a working platform while timbering or installing pipe and trolley wire.

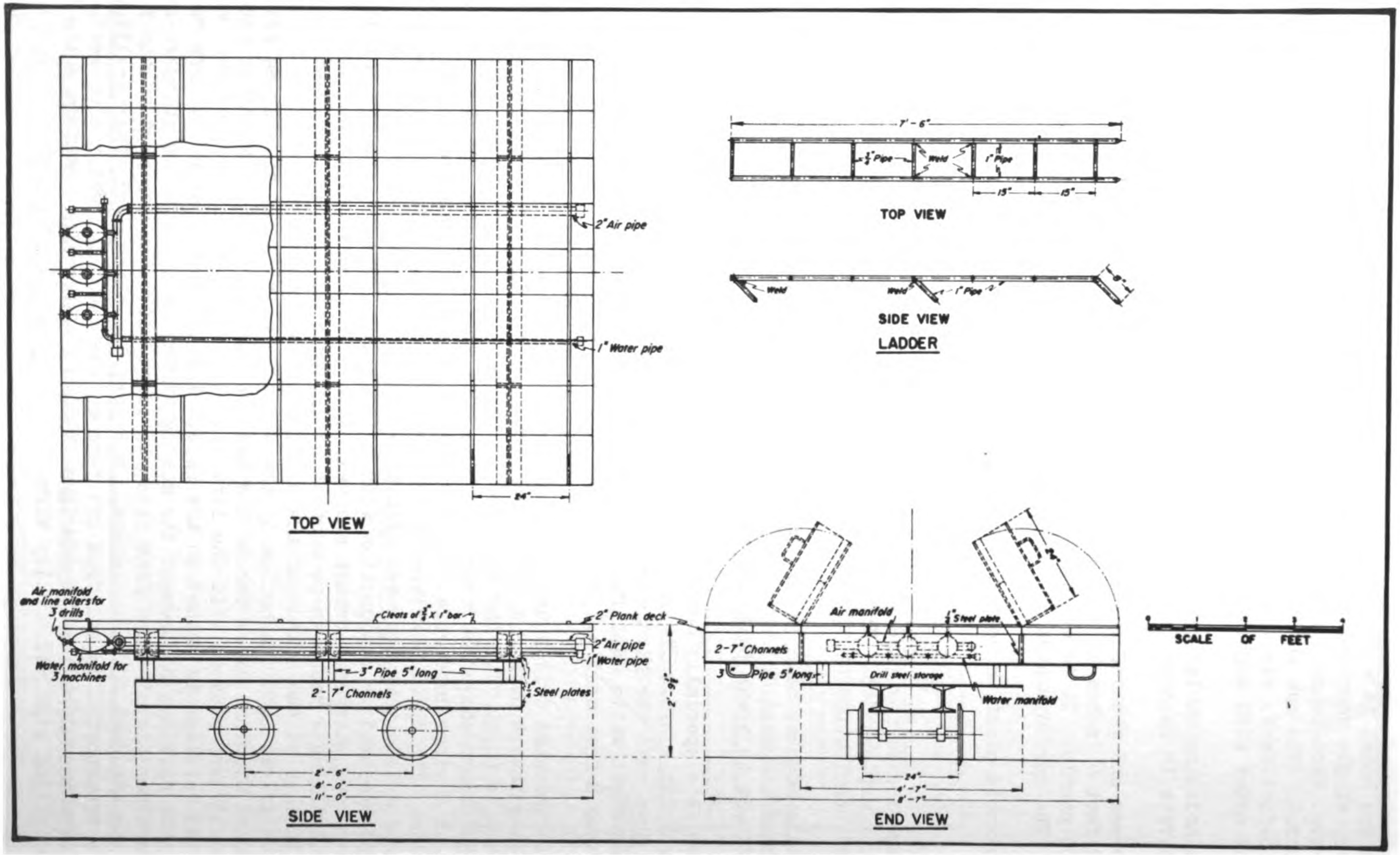

Figure 7. - Carriage and ladder for air-leg drills, Sunrise mine, Platte County, Wyo.

The rounds in waste have a total of 35 to 40 holes, of which 5 are burn-cut holes. The rounds are drilled approximately 8 feet deep and are loaded and blasted as soon as drilled and the equipment has been removed from the face. Electric caps of standard delay are used to detonate the rounds. The explosive used is 45-percent dynamite, which is standard in all blasting at the mine. A compressed-air-actuated water blast is used to allay dust in the headings during blasting.

Loading broken rock begins when the face of the heading is cleared of powder fumes. The muck pile is wet down before loading and when necessary to allay dust during loading. Rock is loaded with a rocker shovel equipped with a conveyor that facilitates loading the back end of the cars. The gage of the loader is 36 inches, and U-beam slide rails are provided for it when in use at the face. The loader is transported to and from the face on a pony truck with 24-inch gage, the gage of the haulage levels.

Timber, pipelines, ventilation tube, and electric lines are installed when necessary, and the cycle is repeated.

Unframed drift sets of 10- by 10-inch or 10- by 12-inch timber are used in the haulage drifts in waste where ground requires support. Caps and collar braces are held in position by cleats (scabs). Slough from the back is controlled in the untimbered parts of the haulage drifts by installing steel pins in the walls about 8 feet 3 inches above the track. The pins are 1-1/2 inches in diameter and 30 inches in length. They are installed in pairs in holes drilled on about 8-inch centers and protrude about 12 inches into the drift. Steel plates, 12 by 12 inches square, are placed on the pins, and caps are placed on the plates. Spreaders and lagging complete the timbering. Trolley wire, electric lines, and pipelines are suspended from the caps.

Haulage drifts under the stopes are driven by jackhammers mounted on stinger bars (fig. 8). The typical round uses a V-cut and consists of 28 holes, 6 to 7 feet deep. Detachable bits are used in drilling these headings which are in ore. The bits are sharpened by hot milling.

The haulage drifts under the stopes are supported by drift sets of 10- by 12-inch timber spaced on approximately 6-foot centers, except at draw positions. If the ground becomes heavy, additional sets are installed between the regular sets.

DEVELOPMENT OF GRIZZLY CAVING BLOCKS

Grizzly caving blocks are developed by drifts on the haulage, grizzly, and undercut levels. Supply and draw raises are driven from the haulage level to the grizzly level, and finger raises are driven from the grizzly level to the undercut level (fig. 9).

Haulage drifts are driven near the margins of the ore body and also across it at centerline intervals of 60 feet. The grizzly level is 30 feet above the haulage level and is developed by supply and grizzly drifts. The supply drifts are driven near the margins of the ore body and across the center of the stopes. The grizzly drifts are driven across the stope on 30-foot centers and parallel to the haulage drifts below. They are timbered by drift sets of 10- by 12-inch Oregon spruce. The undercut drifts are driven 14 feet above the grizzly drifts or 21 feet bottom to bottom. They are parallel to the grizzly drifts and are spaced on centerline intervals of 15 feet. They are not timbered and are about 5 feet wide by 7 feet high. The costs of driving the undercut drifts and all work done from these drifts are

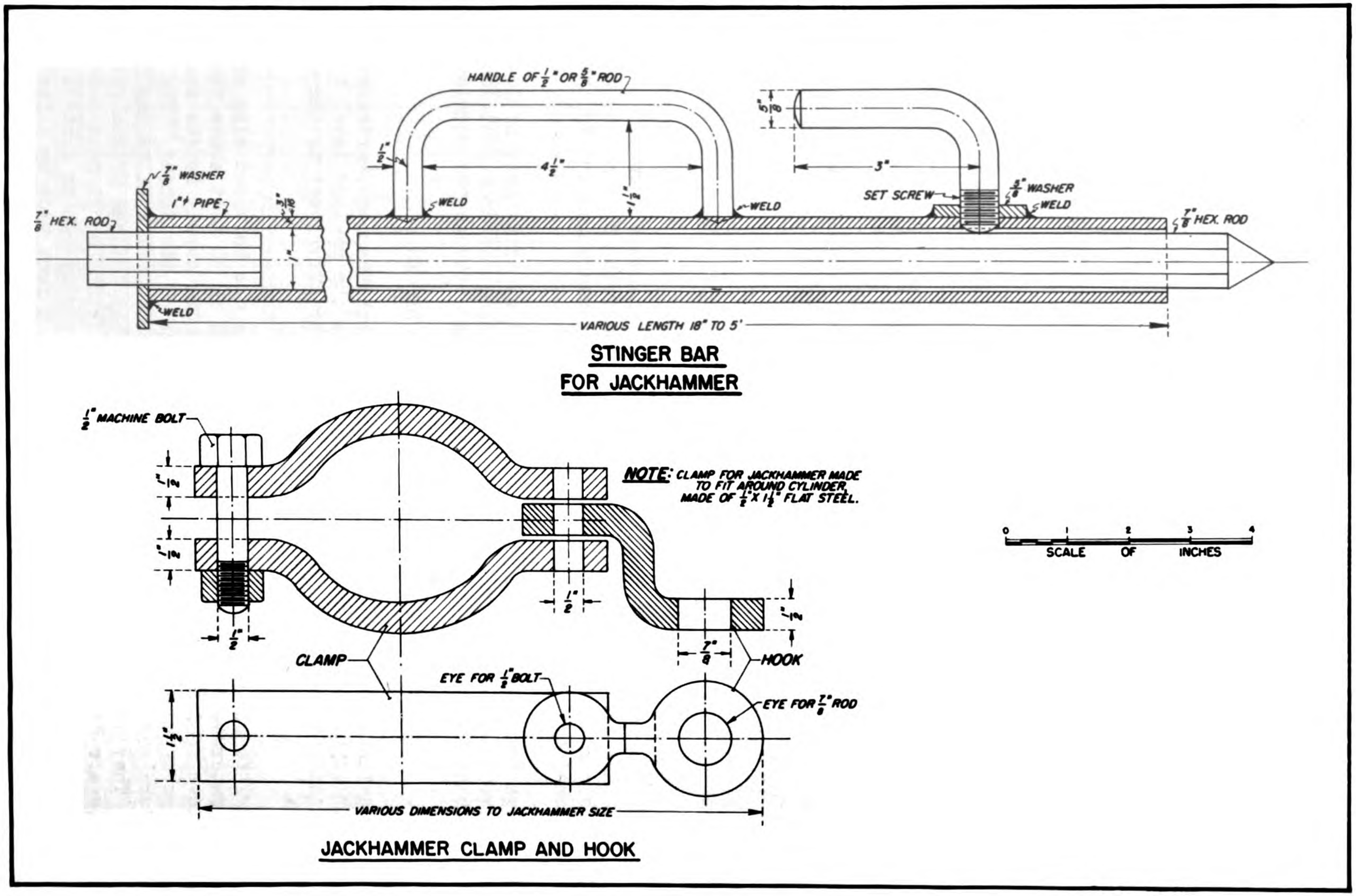

Figure 8. - Jackhammer stinger bar, clamp, and hook, Sunrise mine, Platte County, Wyo.

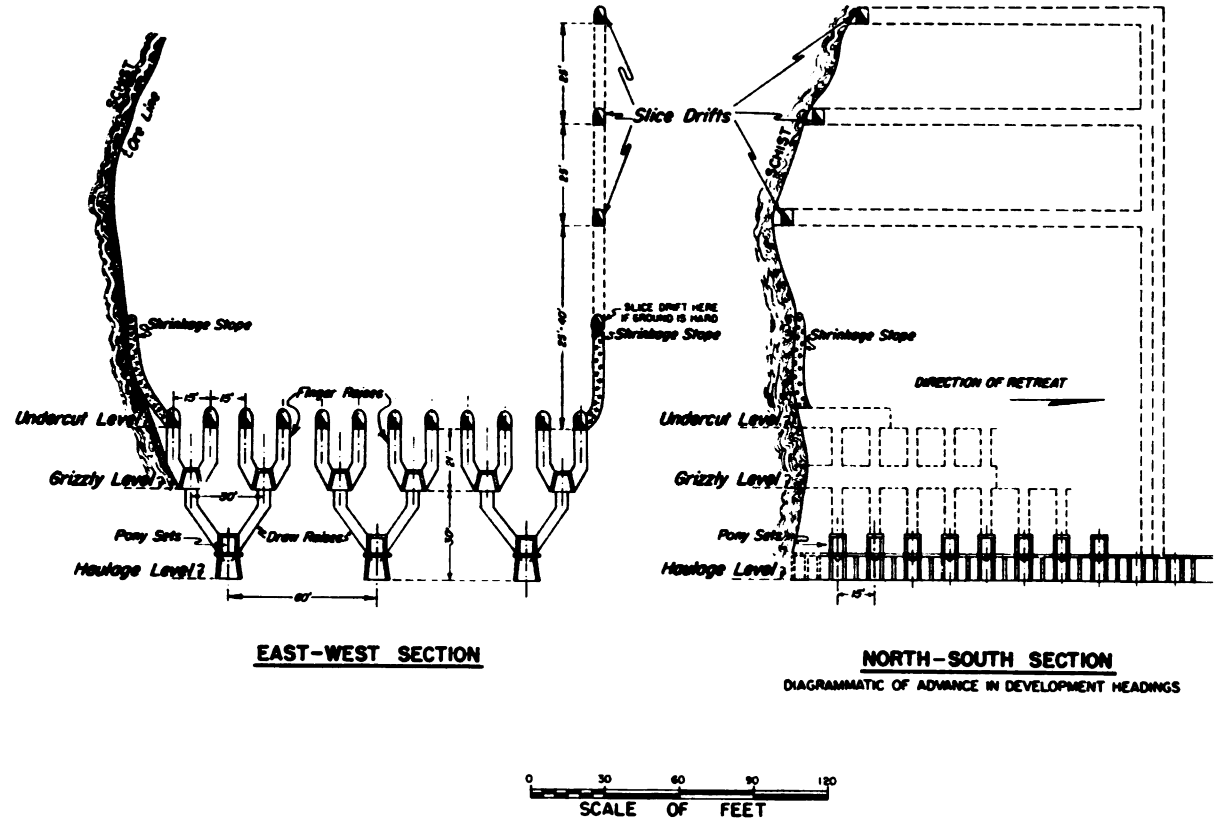

Figure 9. - Generalized sections through grizzly caving block, Sunrise mine, Platte County, Wyo.

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considered as part of the mining costs. Supply drifts are equipped with track and trucks for transporting timber and other supplies on the grizzly level.

The rounds drilled in the grizzly and undercut drifts have V cuts. The average round drilled in the grizzly drifts has 18 holes drilled 6 feet deep, and the rounds in the undercut drifts generally have 14 holes drilled 6 feet deep.

The rounds are blasted by 45-percent dynamite detonated by No. 6 blasting caps. Nine-foot lengths of fuse are used in blasting the rounds, which are spit by 2 men, as a safety regulation prohibits 1 man from lighting more than 10 fuses when blasting a round.

Hand shoveling is kept to a minimum when driving the grizzly and undercut levels. The rounds are blasted to throw as much broken ore into the raises as is possible.

Supply raises are driven on inclinations of 65° from the haulage level to supply drifts on the grizzly level. They are cribbed and have a cross section of 5 feet by 7 feet in the clear. The raises have a manway and timber slide. Single-drum, compressed-air-driven, tugger-type hoists are used to hoist supplies through the raises. Ladders in the manway have 4- by 6-inch sides into which 2- by 4-inch steps are inset. This leaves ample toe room and cleaning space between the ladder and the bottom of the raises.

Draw or main raises are spaced in pairs along the haulage drifts on 15-foot center lines. Pony sets are installed above the haulage level, and the draw raises are driven from them normal to the drifts. The inclination of the raises is 55° until their center lines are 15 feet from the center line of the haulage drifts (fig. 9). The raises are timbered by cribbing where support is deemed necessary, which is not too frequently. The raises have a 4-foot-square cross section in the clear.

Finger raises are driven in pairs on each side of the grizzly level above each draw or main raise. They are driven normal to the grizzly level from the bearing set cutout to the undercut level. The timber in the grizzly level at the mouth of the finger raises is protected by bearing sets (fig. 10). Seventy-five-pound rail is installed near the top and center of the bearing sets. The top rails protect the drift timber, and the lower rails control the flow of broken ore from the finger raises.

Rounds in the raises generally consist of 10 holes. They are drilled with self-rotating stopers, using 7/8-inch steel and detachable bits.

DEVELOPMENT OF SLUSHER CAVING BLOCKS

Slusher caving blocks are developed by haulage, slusher, and undercut drifts, and finger raises (fig. 11). The spacing of the development headings is different from that of the headings in the grizzly caving blocks.

Haulage drifts are driven through the ore body on centerline intervals of 150 feet. Slusher drifts are driven at right angles to the haulage drifts at intervals of 30 feet. The bottoms of the slusher drifts are 6 feet above the top of rail on the haulage level. Slusher drifts are timbered by 10- by 12-inch drift sets on 6-foot centers. The sets are 5 feet wide by 7 feet high in the clear. Drilling and blasting in the slusher drift is similar to that in the grizzly drift.

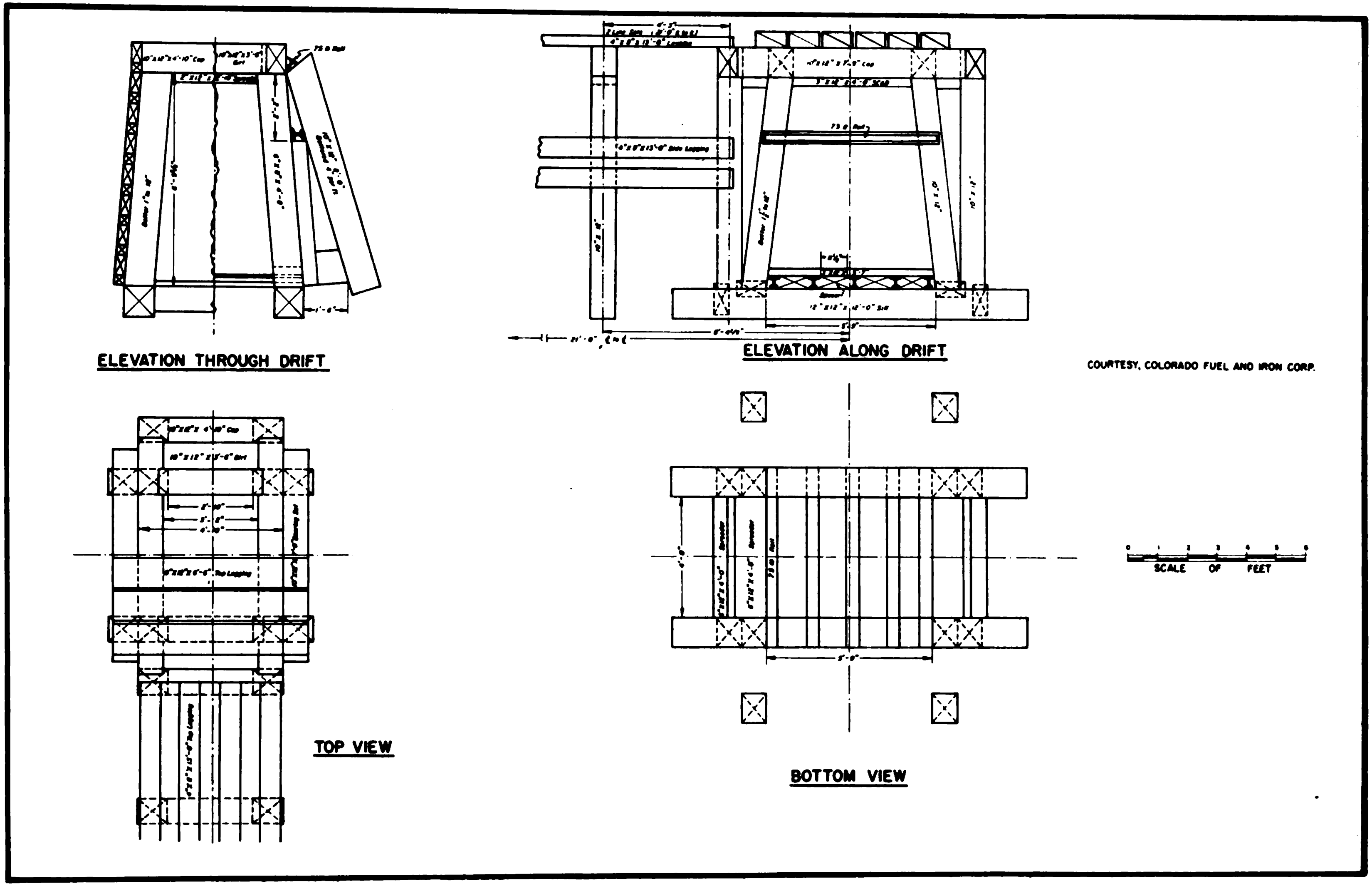

Figure 10. - Grizzly set, grizzly caving block, Sunrise mine, Platte County, Wyo.

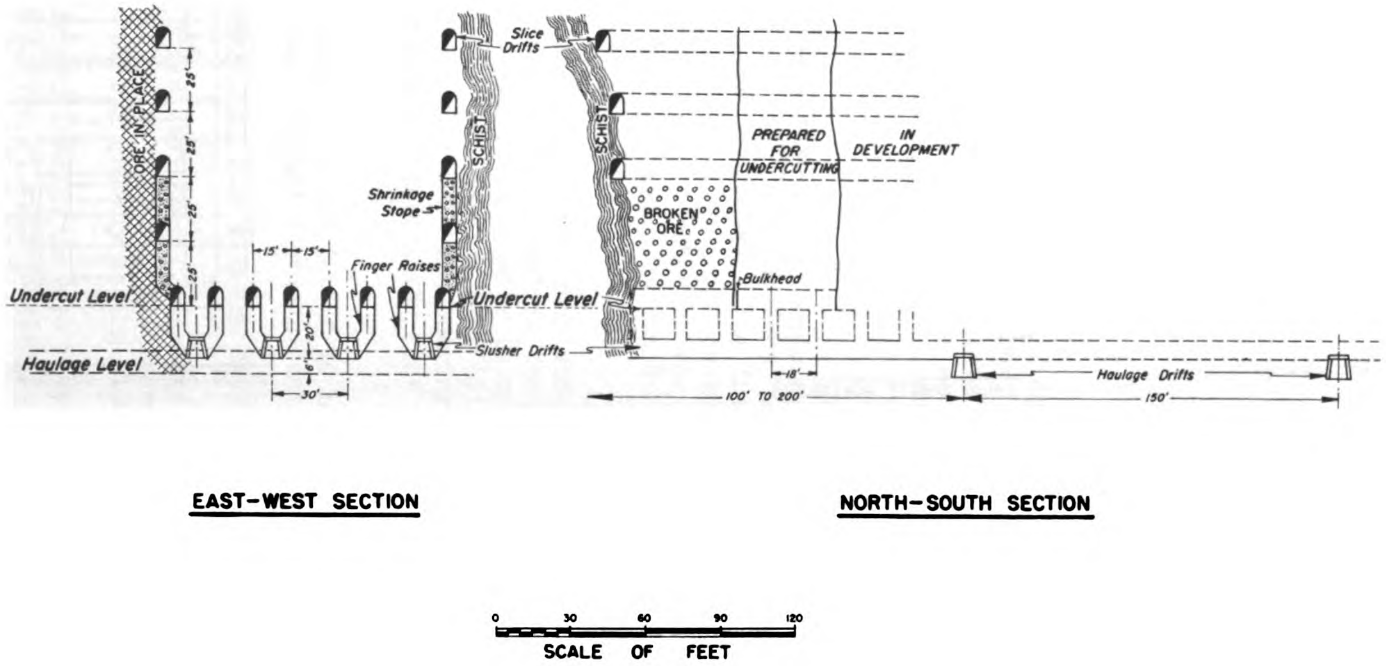

Figure 11. - Generalized sections through slusher caving block, Sunrise mine, Platte County, Wyo.

The undercut level is 20 feet above the bottom of the slusher drifts. The undercut drifts are on 15-foot centers and parallel to the slusher drifts. Undercut drifts are also driven along the margins of the ore body. The drifts have a 5- by 7-foot cross section and are advanced by methods similar to those used in undercut drifts in the grizzly caving block.

Finger raises in slusher blocks are in pairs on either side of the slusher drifts at centerline intervals of 18 feet. They are driven in a similar manner to the finger raises in grizzly caving blocks. The timbering at the mouth of the finger raises is different from that in the grizzly caving block (fig. 12).

All rock broken above the haulage level is loaded into the cars by a 4-foot scraper operating on the slusher level. The scrapers ride on 40-pound rails that prevent gouging and ripping of the bottom of the slusher drifts. Double-drum, 25- or 40-hp., electric slusher hoists are used. They are equipped with wire rope, 5/8 inch diameter on the pull drum and 1/2 inch for back pull. Loading ramps over haulage drifts are made of steel plates and rails. Ramps have laggings on the sides to prevent spillage into haulage drifts (figs. 13 and 14).

DRILLING IN DEVELOPMENT DRIFTS

Jackhammers are used to drill all drift rounds in ore. Stinger bars are used as mountings for the hammers (fig. 8). The stingers are made of 1-inch pipe in lengths varying from 18 inches to 5 feet. A 7/8-inch washer and 7/8-inch, hexagonal rod are welded to one end of the pipe. A length of 7/8-inch rod, sharpened on one end, is inserted into the other end of the pipe. This rod can be slid in the pipe until the desired length of the stinger is attached. The rod is then locked in position by a set screw. Clamps made of 1/2-inch by 1-1/2-inch flat steel are fitted around the jackhammer cylinders. A hook made of 1/2-inch rods fastens to the clamp and has an eye to fit over the rod welded on the stinger bar. In drilling a round, a lagging is laid on the bottom of the drift and the stinger bar and jackhammer are advanced along the lagging as the drilling progresses. The chucks of the jackhammers accommodate 7/8-inch hexagonal drill steel, and detachable bits are used for drilling.

MINING METHODS PREVIOUSLY USED[3]

The first mining was done with a steam shovel operating in ore exposed on a hillside. Overlying cap rock was stripped and the ore was mined by usual open-pit methods, except that benches and berms were not left.

Straight open-pit methods were discontinued soon because of the increase in the grade of the railroad track leading from the mine. A shaft was sunk, drifts were driven under the ore body, raises were driven to the floor of the pits, and glory-hole methods were initiated. A small steam shovel operated in the wider part of the pit, shoveling the ore directly into mill holes. Scrapers were used to transport broken ore to chutes in the narrow parts of the mine.

In 1929 the north end of the pit had attained a depth of 500 feet. There was still a large tonnage of ore farther north that was overlain by capping too thick for economical stripping and milling. A block-caving system was adopted to mine this ore. The method has been changed several times since its adoption. The grizzly-caving-block method now used is a result of these modifications. In the

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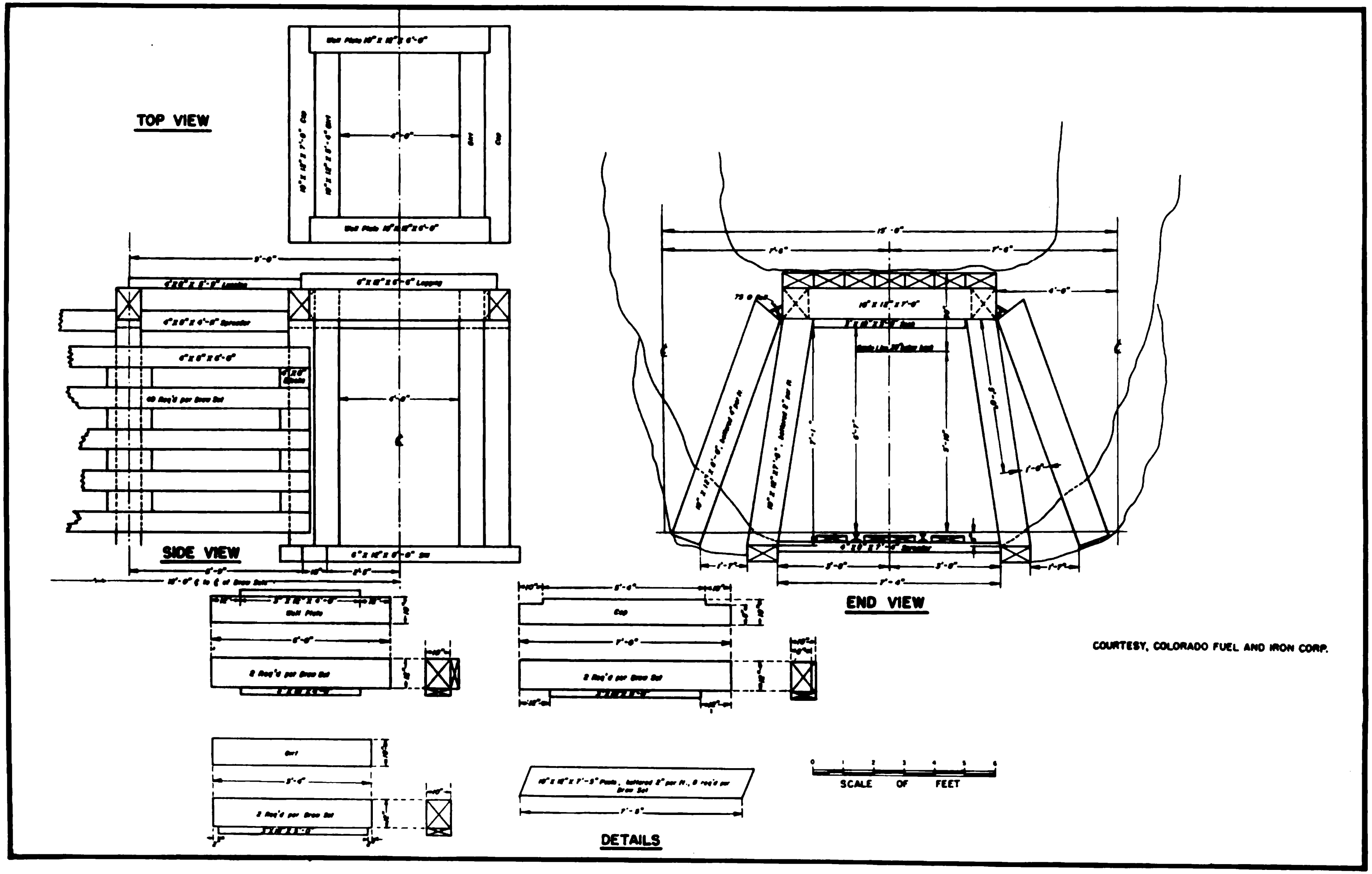
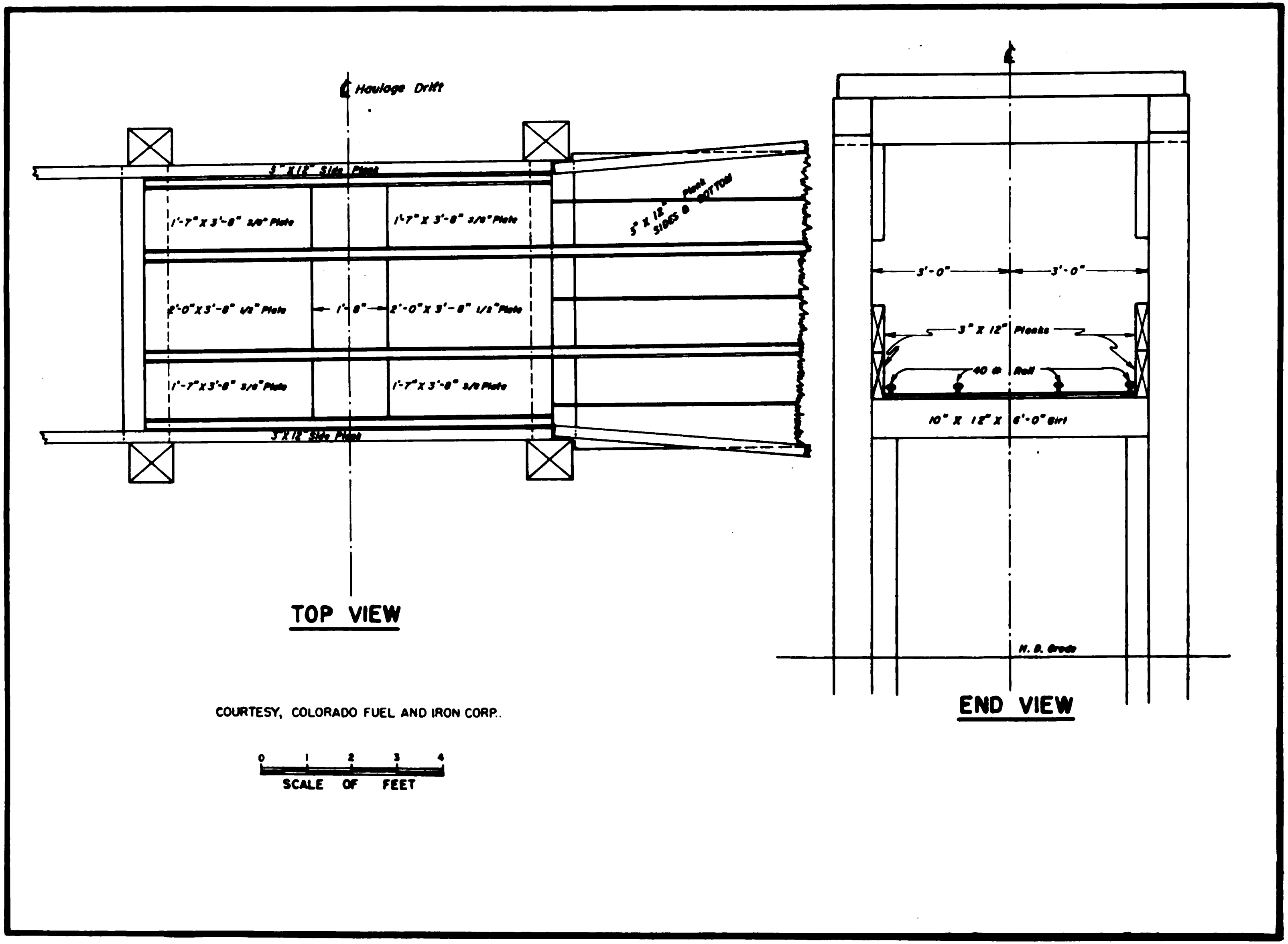
[3] Abstracted in part from Rupp, G. H., Block-caving at the Sunrise Iron Mine, Wyo.: AIME Tech. Pub. 1069, May 1939, 16 pp.



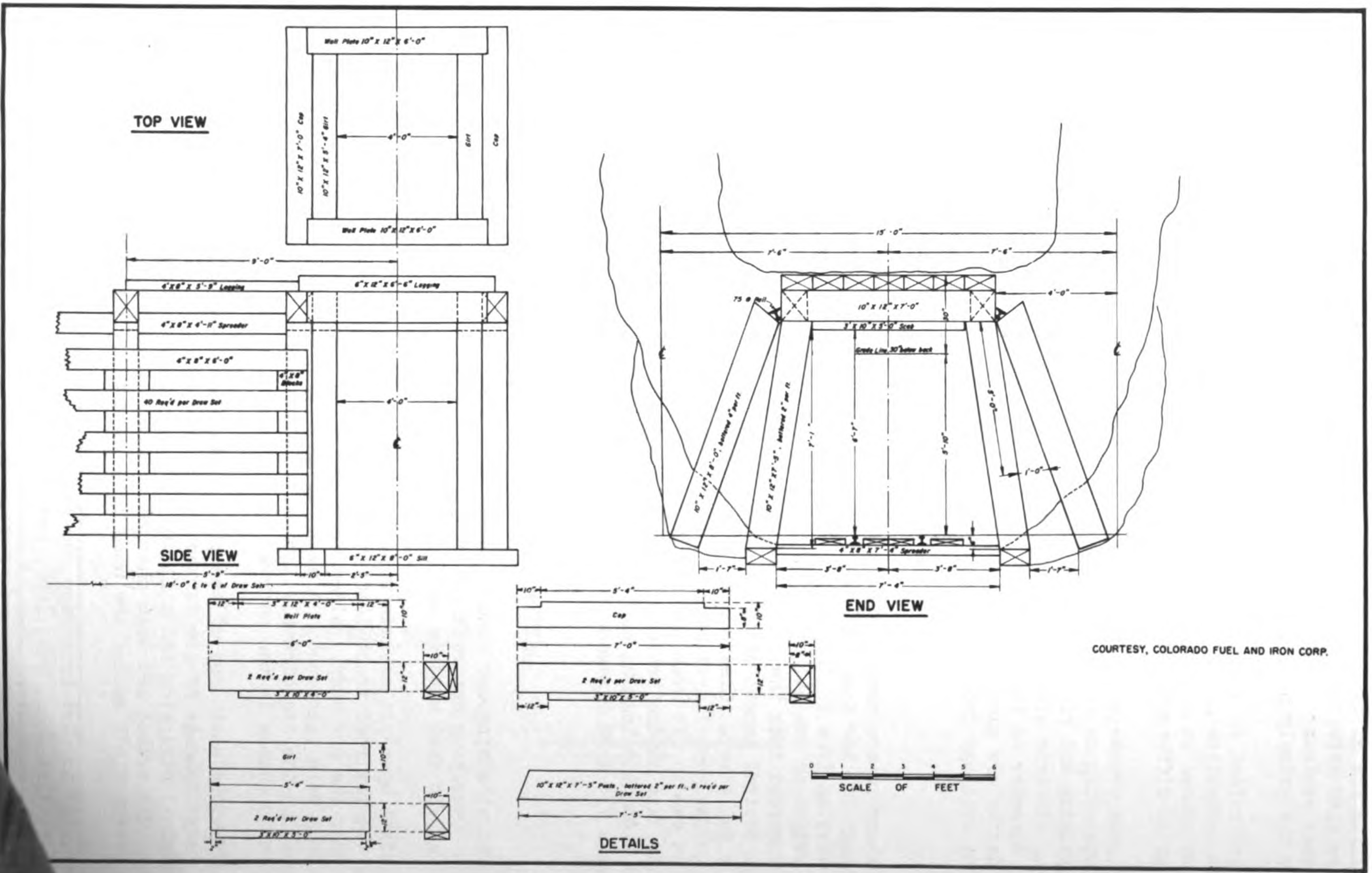
COURTESY, COLORADO FUEL AND IRON CORP.

Figure 12. - Grizzly set, slusher caving block, Sunrise mine, Platte County, Wyo.



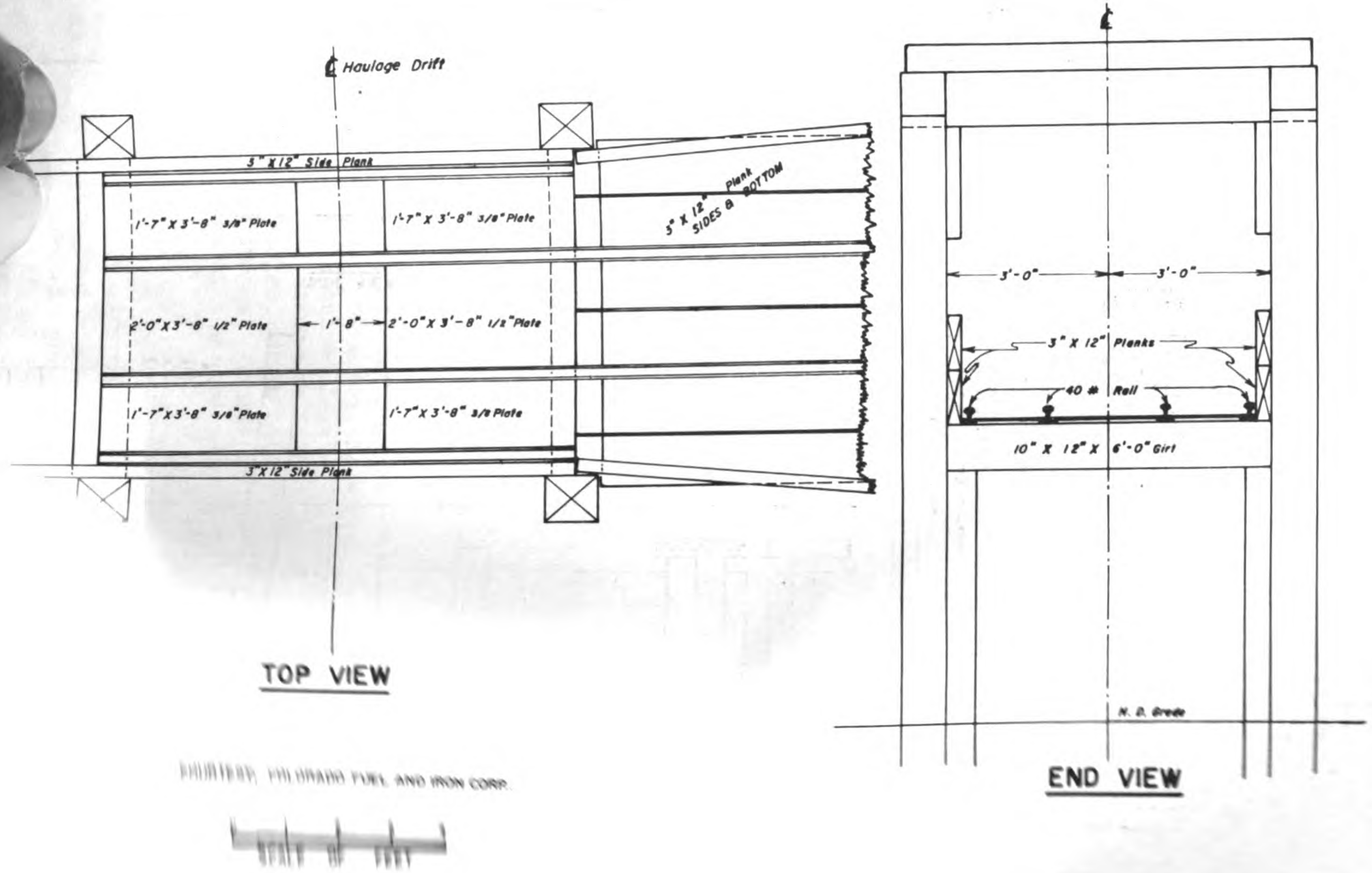
COURTESY, COLORADO FUEL AND IRON CORP.

Figure 13. - Loading ramp, slusher caving block, Sunrise mine, Platte County, Wyo.



COURTESY, COLORADO FUEL AND IRON CORP.

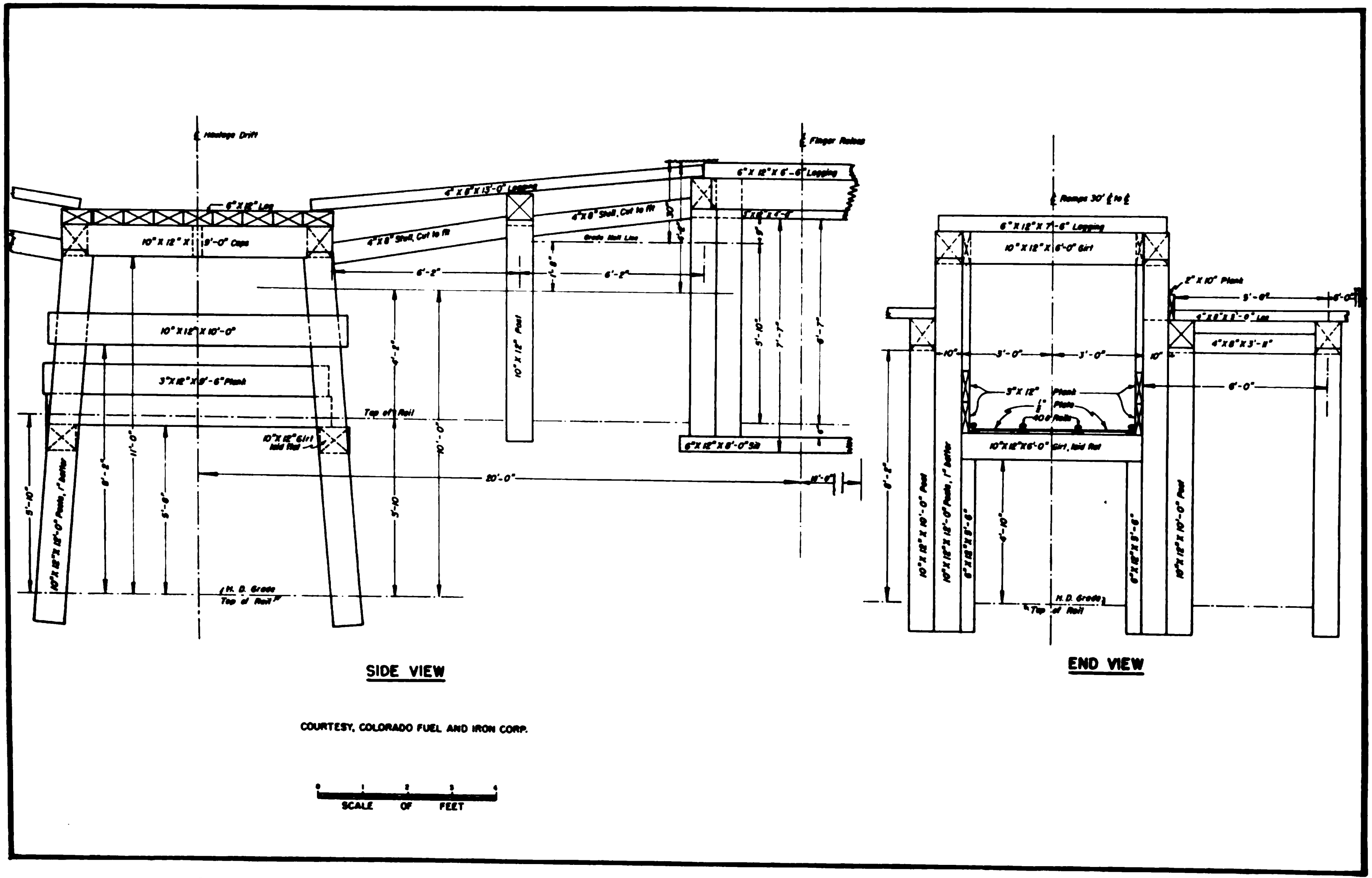
Figure 12. - Grizzly set, slusher caving block, Sunrise mine, Platte County, Wyo.



COURTESY, COLORADO FUEL AND IRON CORP.

Figure 11. [illegible] Sunrise mine, Platte County, Wyo.

Original from THE OHIO STATE UNIVERSITY



COURTESY, COLORADO FUEL AND IRON CORP.

Figure 14. - Timber detail, ramp cut out, slusher caving block, Sunrise mine, Platte County, Wyo.

Original from THE OHIO STATE UNIVERSITY

first work, grizzlies were made with an advance set instead of the bearing set now used. Three small finger raises were driven from the advance set to the undercut level, which resulted in 6 finger raises instead of 2 from each grizzly position. It has been found more economical to develop sublevels and transfer the ore to the main haulage than to drive long branch raises. Some changes have been made in spacing the development headings and in timbering the grizzly levels.

In 1941 a sublevel caving method was adopted, and mining by this method continued until 1953.

Blocks were developed for sublevel caving by first driving main haulage-level drifts in the ore body. Main raises for ore passes and handling supplies were driven at intervals of 200 feet from the haulage level to near the top of the block. Sublevel drifts, 25 and 50 feet below the top of the block, connected the raises. Mining or slusher drifts were driven at right angles to one side of the upper sublevel at intervals of 25 feet. Stub drifts for slusher-hoist installations were driven on the side of the sublevel opposite the mining drifts. Raises 4 feet by 4 feet were driven from the lower sublevel to near the intersection of the upper sublevel and the mining drifts. The upper sublevel was used to transport supplies to connecting mining drifts. Ore broken in mining was slushed along the mining drifts to the raises where it passed to the sublevel below. The ore was then slushed along the lower sublevel to the main raises where it passed to the main haulage level. This arrangement eliminated interference between handling supplies in upper sublevel and haulage by scraper in the lower one.

As extraction of ore from the upper level approached completion, the lower sublevel was prepared to become the mining sublevel. A sublevel was driven 25 feet below for haulage by scrapers, and raises were driven from the new haulage sublevels to the new mining level. As mining progressed, the process was repeated until the bottom of the block was reached.

Mining began in the end of the mining drifts by driving short finger raises from each side of the drift. The raises were driven from every other set and belled out above the drift. Ring holes from the raises were then drilled and blasted to induce caving. Mining was carried on above four drifts at one time, although it was sometimes necessary to stop mining in one of the drifts to do maintenance work on the timber.

Sublevel caving was discontinued because the ore was not caved readily by the method. It was necessary to enter the stopes and do considerable drilling and blasting. This method required leaving numerous pillars, which hampered caving operations from below. Excessive dilution resulted because the stopes assumed characteristics of open stopes, which permitted waste from the weak side walls and capping to run into the stopes. Considerable development work was necessary because mining from both sides of the sublevel drifts was not successful.

MINING

Blocks 100 to 200 feet high are mined by block caving at present. Blocks as high as 400 feet have been mined in the past. The methods used to induce caving above the undercut level in the grizzly or standard caving blocks and the slusher caving blocks are essentially the same. The differences in the two methods are development and method of loading the ore broken by caving.

The sequence of operations for the two methods is as follows:

Grizzly or standard caving block -

1. Haulage drifts,
2. Draw and supply raises,
3. Grizzly drifts (supply drifts are driven on this level),
4. Finger raises,
5. Boundary raises, slice drifts, and shrinkage stopes,
6. Undercutting.

Slusher caving block -

1. Haulage drifts,
2. Slusher drifts,
3. Finger raises,
4. Boundary raises, slice drifts, and shrinkage stopes,
5. Undercutting.

All of the above processes are conducted simultaneously, and each operation is sufficiently in advance of the one following to avoid interference and to have the ore body prepared for progressive caving.

The ore body is divided into panels 120 to 180 feet wide for mining by grizzly caving blocks. The panels extend longitudinally more or less across the strike of the ore body from one limit to the other. Each panel delivers its broken ore to two or three haulage drifts, depending on its width.

The parts of the ore body mined by slusher caving blocks are divided into panels 90 to 120 feet wide. The length of the panels is approximately 100 feet, except where irregularity of the boundary of the ore body increases or decreases this dimension. The panels are divided into blocks 36 to 54 feet long during undercutting. Slushing has been done for as much as 200 feet where irregularity of the ore body made it necessary. Each panel has three or four slusher drifts through which ore is loaded into cars on the haulage drift.

In either caving method, as stoping progresses from one end of a panel in the direction of retreat, mining is begun in the next adjacent panel after the ore has been drawn and waste settles in the finished stope. Thus the retreat is both across the ore body by each panel and roughly along its strike by the panels.

Block-caving mining methods depend on two operations: (1) Loosening the block from surrounding rock or ore by weakening or cutting the boundaries, and (2) undercutting or blasting and removing a layer of ore from beneath the block to be mined. These practices are not uniform at different mines because of physical characteristics of the ore and economics of the operations.

Caving blocks at the Sunrise mine are loosened from rock or adjacent blocks of ore by slice drifts and shrinkage stopes. Two-compartment, cribbed boundary raises are driven from the grizzly level in standard caving blocks and from the undercut level in slusher caving blocks. Slice drifts are driven from the boundary raises at 25- to 40-foot vertical intervals, depending on the hardness of the ore. The drifts are 5 feet wide by 7 feet high. They are mucked by slusher scrapers. A 7-foot cut is taken out of the back of the drifts after they have been driven to their required lengths. Shrinkage stopes are mined from finger raises along the boundaries of the block. The stopes are carried 6 feet wide for a height of 25 to 40 feet. All broken ore feeds through the finger raises.

Undercutting at the top of the finger raises begins after the slice drifts and shrinkage stopes are completed. When the undercut drifts have been driven to their required length, alternate drifts are sideswiped, removing about 3 feet of ore from each side of the drift. The pillars between the undercut drifts are then completely cut off by drilling rings of 10 or more holes at 3-foot intervals in the sides and backs of the enlarged drifts (fig. 15). If the pillars are not completely removed, they are drilled and blasted again.

In the grizzly or standard caving blocks, ore is drawn through the fingers onto grizzlies. Lumps of ore, too large to pass through the grizzlies, are broken with sledge hammers or pneumatic pavement breakers. The ore that is too hard to be broken in this manner is block holed and blasted. Boulders that firmly choke finger raises at their mouths are drilled with stopers. Fingers choked some distance from the mouth are opened by "high shots" or by bundles of dynamite fastened to long sticks and placed in openings between the boulders. Because several finger raises are opened at the same time, instantaneous electric caps are used for high shot work to eliminate one blast dislodging the charge of explosives in a nearby finger raise. Four-foot fuse is used in blasting block holes.

Ore from the slusher caving block passes directly from the finger raises into the slusher drift. While waiting to load trains, slusher-hoist operators scrape ore to positions near the loading ramp, open finger raises and break lumps of ore too large to pass through the openings in the plates of the ramp. Block holing is done near the finger raises.

Wear in the slusher drift is not a particular problem because the low lift of the blocks results in a comparatively short use-life for the drifts. Pillar failure causes more trouble and results in drift maintenance and reopening of finger raises.

DRAW CONTROL

Control of drawing ore from the chutes is one of the most important factors in successful block-caving. At the Sunrise mine, accurate graphs are made, showing the draw from the chutes as compared with the estimated total tonnage to be drawn. The graphs are prepared to scale on both north-south and east-west sections and have a 40 percent allowance for swell of broken material. For general purposes the graphs are brought up to date weekly. Production from the chutes is plotted daily on large-scale charts kept in the mine office to guide the operating crews. The graphs and charts show when fingers and stopes are being pulled too rapidly or too slowly.

Practical experience and close observation are important requisites for success of the operation. Repair work in drifts or raises, behavior of certain fingers, grade of ore drawn, control of dilution, and pressures exerted on the drawing section are factors affecting drawing.

UNDERGROUND TRANSPORTATION

The broken ore in the standard caving block enters the draw raises after passing through the grizzlies. It is drawn from these raises through chutes with wooden sides and bottoms (fig. 16). The chute gates are hand-operated, steel arc gates, 29 inches wide and 24 inches high. The chute pullers stand in pony sets above the haulage level when drawing the chutes.

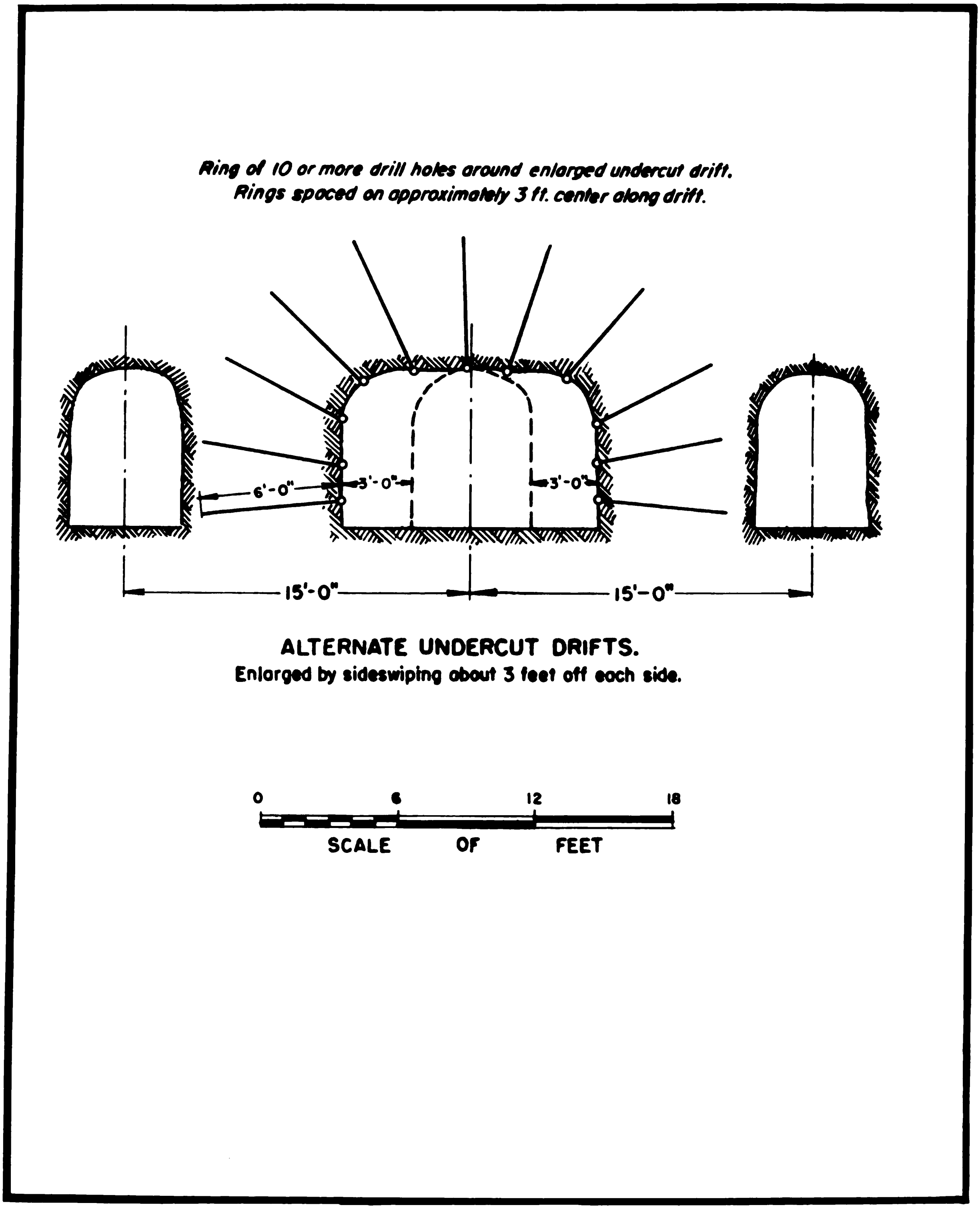
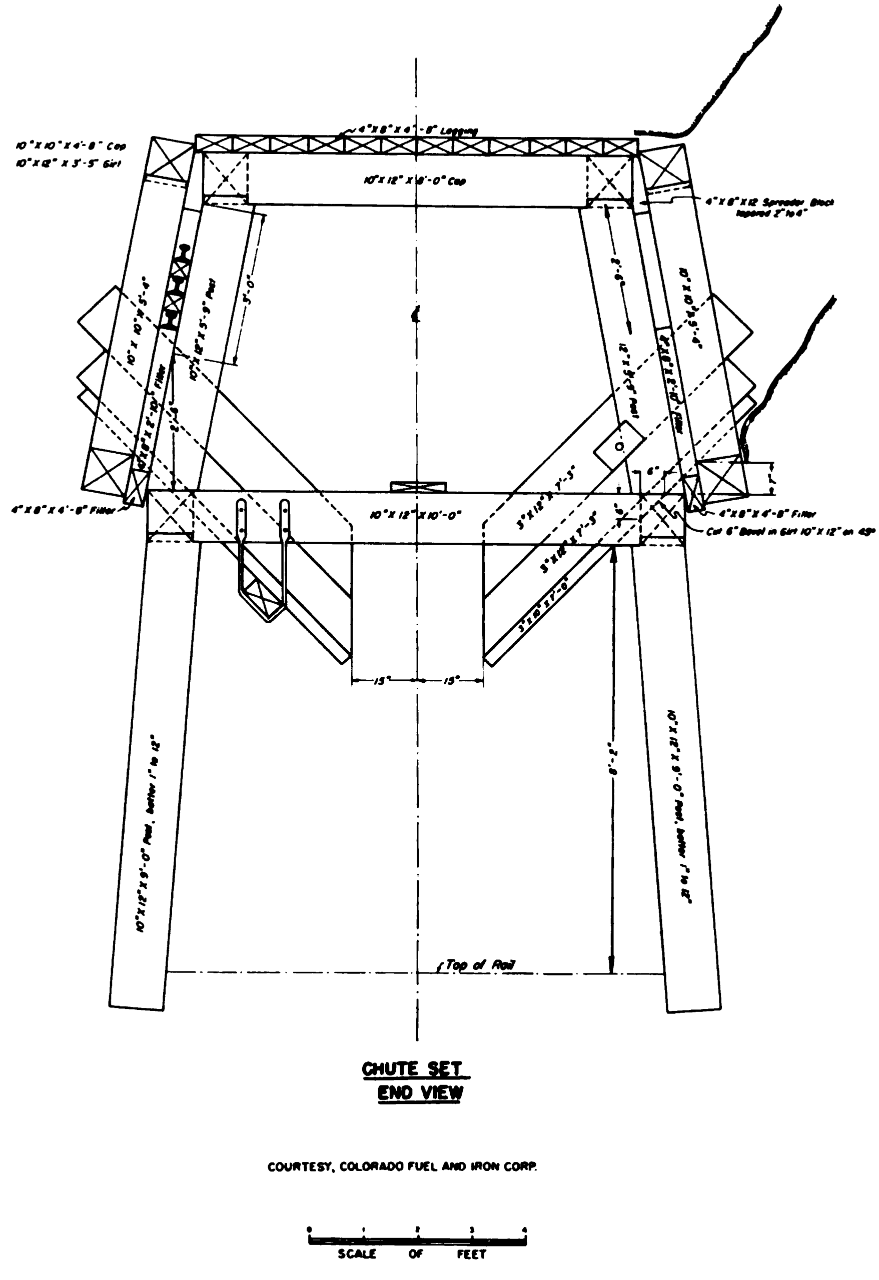

Ring of 10 or more drill holes around enlarged undercut drift.
Rings spaced on approximately 3 ft. center along drift.
6'-0"
3'-0"
3'-0"
15'-0"
15'-0"
ALTERNATE UNDERCUT DRIFTS.
Enlarged by sideswiping about 3 feet off each side.
0
6
12
18
SCALE OF FEET

Figure 15. - Method of cutting off pillars, undercut level, Sunrise mine, Platte County, Wyo.



CHUTE SET
END VIEW

COURTESY, COLORADO FUEL AND IRON CORP.

Figure 16. - Chute set, grizzly caving block, Sunrise mine, Platte County, Wyo.

Haulage is done by electric trolley locomotives of various sizes, 6- to 15-ton, and 120-cubic foot cars. The smaller motors are used to switch cars in development headings. The cars are side dumped at the shaft pockets by a pneumatic device operated by one of the motor crew. Sixty-pound rail on 24-inch gage is used as track. Spring switches are installed in the track with their throw lined in the direction of the most traffic. Hand-operated, block-signal systems are used on the haulage levels.

The grizzlies over the shaft pockets slope at 45° from the bottom of the track ties to a point 42 inches below the ties. They then extend horizontally over the pockets to a walkway on which the grizzly men work. Large pieces of timber are removed from the ore on the grizzlies, and the broken wood is put on cars and caged to the surface.

Trucks are loaded with mine timber on the surface and are caged through the supply compartment of the shafts. Explosives and other supplies are transported in special containers.

Electric signal systems consisting of both bells and lights are used to begin the movement of cages and skips. The cage tender and skip loader are the only persons authorized to signal the hoistman. Telephones are located at various parts of the mine for communication with the surface and other parts of the mine.

Air whistles, located at draw raises and slusher drifts, are used by brakemen to signal motormen when loading ore trains in the stopes. Air whistles are used also to contact men in the haulage levels when blasts on grizzlies or in finger raises are to be detonated. All drifts are guarded during such blasts.

AUXILIARY OPERATIONS

Drill repair shops, tool rooms, motor and car repair shops, and powder magazines are on the haulage levels. All shops and magazines are well lighted by electricity.

The drill repair shop and toolroom are combined. Small tools, supplies, drill steel and detachable bits are issued from the toolroom.

Mine cars and haulage motors are repaired in underground shops. The shops are supported by concrete and steel. They are equipped with overhead cranes for raising equipment and with pits from which repairs can be made to the under parts of haulage equipment.

Dynamite for one day's use is stored in underground magazines. The magazines are well lighted and ventilated. Boxes of powder are opened and dumped on screens to remove the sawdust. Powder is sacked and issued to the miners upon requisition. Primers are prepared by the magazine attendant. Two lengths of fuse are used, 4 and 9 feet. The 4-foot primers are used in block holing on grizzlies, and 9-foot primers are used in blasting development headings above the haulage level.

Compressed air is furnished by three electrically driven compressors having a combined rated capacity of 11,500 cubic feet per minute. The compressors are housed in the brick building in which hoisting equipment for shaft No. 3 is located. Steel pipe, with 12-inch inside diameter, transports the compressed air from after coolers to the working levels of the operating shafts, and 8-inch supply lines run from the shafts to mining areas.

POWER

Electric power is transmitted from a hydroelectric plant at Guernsey Dam on the North Platte River not far from the mine. The electric system is interconnected with transmission lines from other electric power developments in the region.

High-voltage current is transformed on the surface to 2,300-, 440-, and 220-volt alternating current for transmission into the mine. The trolley locomotive operate on 250-volt direct current. Slusher hoists and some of the ventilation fans operate on direct current.

Alternating current is converted to direct current by two motor-generators and a rectifier connected in parallel. The motor-generators, as a unit, and the rectifier operate independently or in conjuction, as the load requires. The motor-generators are in the hoist house at No. 3 shaft, and the rectifier is underground near the Central ore body.

The monthly consumption of electricity is approximately 500,000 kilowatt hours.

SUPPLIES

Approximately 120,000 ft. b.m. of timber is used during a month. Most of the timber is shipped from Oregon; the remainder is obtained from forests west of the mine.

One pound of powder is used to produce 4.22 tons of ore and rock hoisted.

PERCENT OF ORE EXTRACTION AND PRODUCTION RATES

Ore extraction from various blocks ranges from 80 to a little more than 100 percent of the estimated tonnage. The average overall extraction from the mine is approximately 85 percent.

Dilution by waste is from two sources, cap rock and waste bands in the ore bodies. The dilution amounts to approximately 6 percent of the material hoisted. Most of the waste is removed from the ore in the picking plant on the surface.

The current production of the mine is 3,100 tons of ore a day. Approximately 18.8 tons are produced by each man-shift of underground labor and about 13 tons a day are produced by all employees at the mine.

VENTILATION

Air circulation is induced by three 6-foot and one 5-foot, electrically driven, propeller-type fans, installed underground. Small, auxiliary fans circulate air in parts of the mine, and compressed air is used as a method of ventilating some undercut drifts and finger raises.

Abandoned shaft No. 2 and fractures and caves in the rock serve as intakes for air. No. 1 and No. 3 shafts serve as air returns.

A recent ventilation survey indicated that the volume of air entering the mine is 92,000 cubic feet a minute. The volume of air exhausted was determined to be 103,000 cubic feet. The difference in the volumes entering into and exhausting from the mine is thought to be caused by unmeasurable quantities of air entering the mine through minute fractures in the rock.

DRAINAGE

The average quantity of water pumped a day is approximately 450,000 gallons. This fluctuates somewhat with the seasons, the heaviest flow being in spring and early summer. The water drains through the mine workings into a sump below the 5th level, from which the water is pumped to the surface in one lift. Approximately 100,000 gallons of the water pumped daily is obtained from drill holes on the third level and is used for domestic purposes at the surface plant and in the town of Sunrise.

The sump below the fifth level has a capacity of 1 million gallons (fig. 3). Four 550-gallon and one 2,200-gallon, electrically driven, centrifugal pumps discharge through a 12-inch steel pipe supported on the bearing sets of the shaft.

WAGES AND BONUS SYSTEM

Wages and fringe benefits are established by negotiations between the management and representatives of labor unions.

Incentive bonus is paid for work in development headings. The work to be done is offered for competitive bidding by employees of the mine. Employees' seniority and ability are considered in awarding contracts. The contract price for the work is broken down into units such as payment for linear foot of advance, timber installed, pipe and trackwork, and linear feet of ditching in a drift.

FIRE PREVENTION

Underground fire-fighting stations have been established at strategic locations in the mine. They are equipped with independent water systems, hoses, and other fire-fighting apparatus. Chemical- and water-filled, 5-gallon, pump-type fire extinguishers are installed in various parts of the mine.

The company owns and maintains oxygen breathing apparatus. Crews are trained in mine rescue in programs in which the Federal Bureau of Mines cooperates.

SAFETY METHODS AND FIRST-AID TRAINING

A safety engineer who organizes a safety program is employed full time at the Sunrise mine. A safety committee meets regularly to discuss safety problems and to make recommendations.

Protective hats, footwear, and glasses are worn by underground employees. The protective footwear includes leg guards, or spats, for all employees breaking boulders on grizzlies.

First-aid stations are established throughout the mine. First-aid and accident-prevention training programs are conducted with the cooperation of the Federal Bureau of Mines.

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